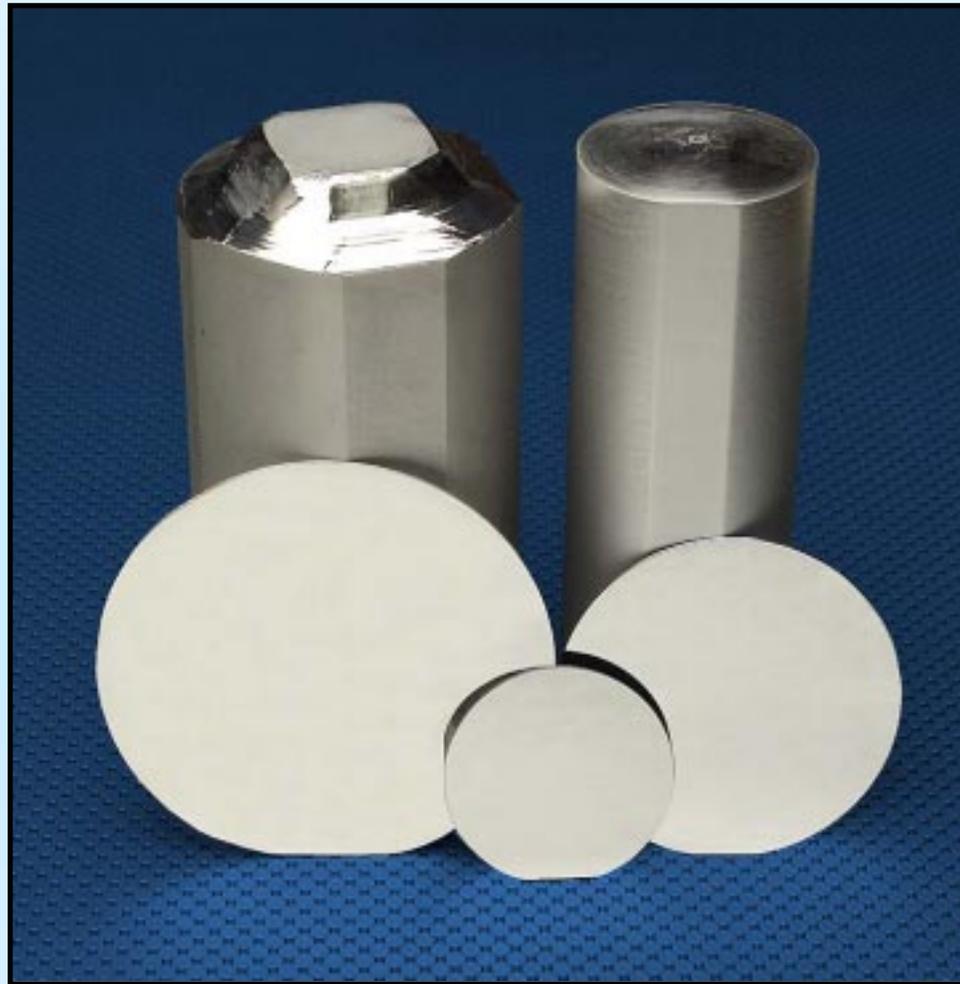


GaSb Crystal Growth and Wafer Polishing

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July, 2001

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Gallium Antimonide crystals and wafers grown at JX Crystals
(2", 3" and 4" wafers available)

ABSTRACT

JX Crystals fabricates diffused-junction GaSb photovoltaic cells. Our low-bandgap cells are used as booster cells in tandem GaAs/GaSb solar cells and for thermophotovoltaic cells for use with combustion heat sources. Our solar cells can be used to power space satellites and our TPV cells can be used in quiet soldier-portable battery chargers.

As a result of our interest in GaSb photovoltaic cells, JX Crystals has grown 2", 3", and 4" GaSb crystals in-house using converted silicon CZ pullers. We then slice these crystals up into wafers. During 2000, we used a total of 70 two-inch wafers, 260 three-inch wafers, and 10 four-inch wafers to fabricate a total of over 5000 GaSb PV cells. Our cell yield was over 90%. Our fabrication process uses a simple diffusion where active junctions are formed in 30 wafers at a time in 1 hour in a furnace costing \$100k.

For our in-house device fabrication, we do not need to polish our wafers. In fact, we simply etch away saw damage prior to diffusion. However, there is a significant interest in the research community in using GaSb wafers for the fabrication of more complex devices using grown epitaxial structures. For this reason and because we already have a significant in-house GaSb capability, JX Crystals has purchased lapping and polishing equipment and we are now beginning to supply 2" and 3" polished GaSb wafers for the epitaxy research community.

GaSb WAFERS FOR EPI DEVICES

HIGH PERFORMANCE EPITAXIAL DEVICES START WITH HIGH QUALITY WAFERS.

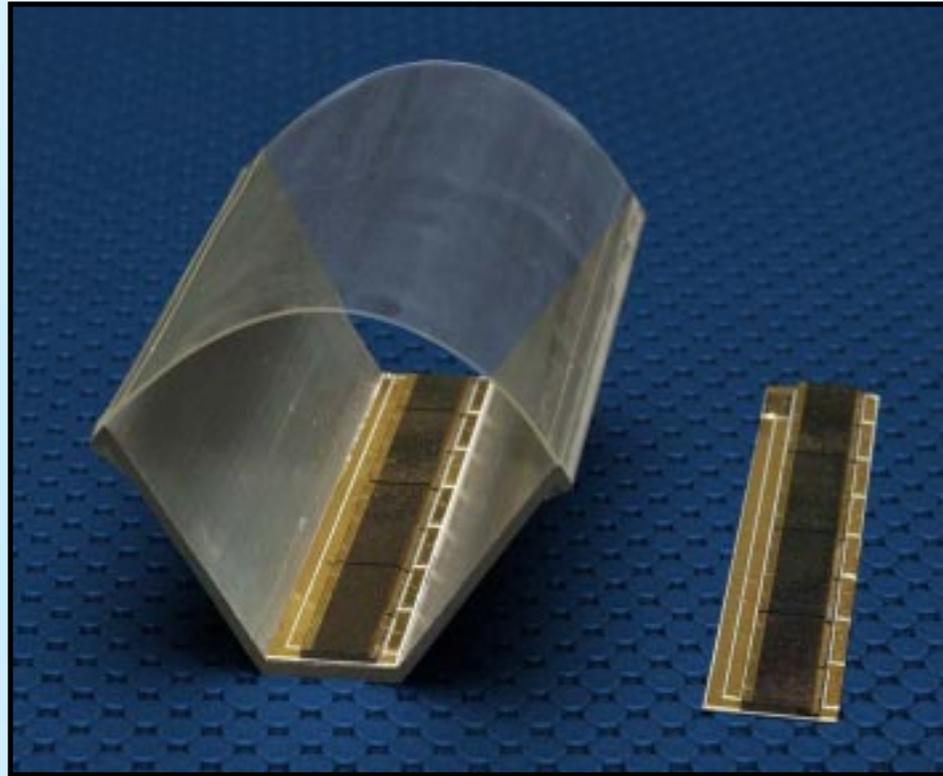
JX Crystals can supply 2", 3" and 4" GaSb polished wafers with very low etch pit density (EPD), any orientation, and either single or double side polishing.

Epitaxy requires a near perfect wafer polish. With limited internal funding, we have been working on producing wafers with an epi-ready polish. Further epi-ready wafer development is required, and could be rapidly achieved if sufficient funding were available.

It is ironic that tens of millions of dollars are being spent on epitaxial growth contracts but no R&D contract support is available for epi-ready polished wafers. Wafers are, after all, the foundation upon which epitaxial devices are built. R&D contract support for epi-ready GaSb wafers will lead to:

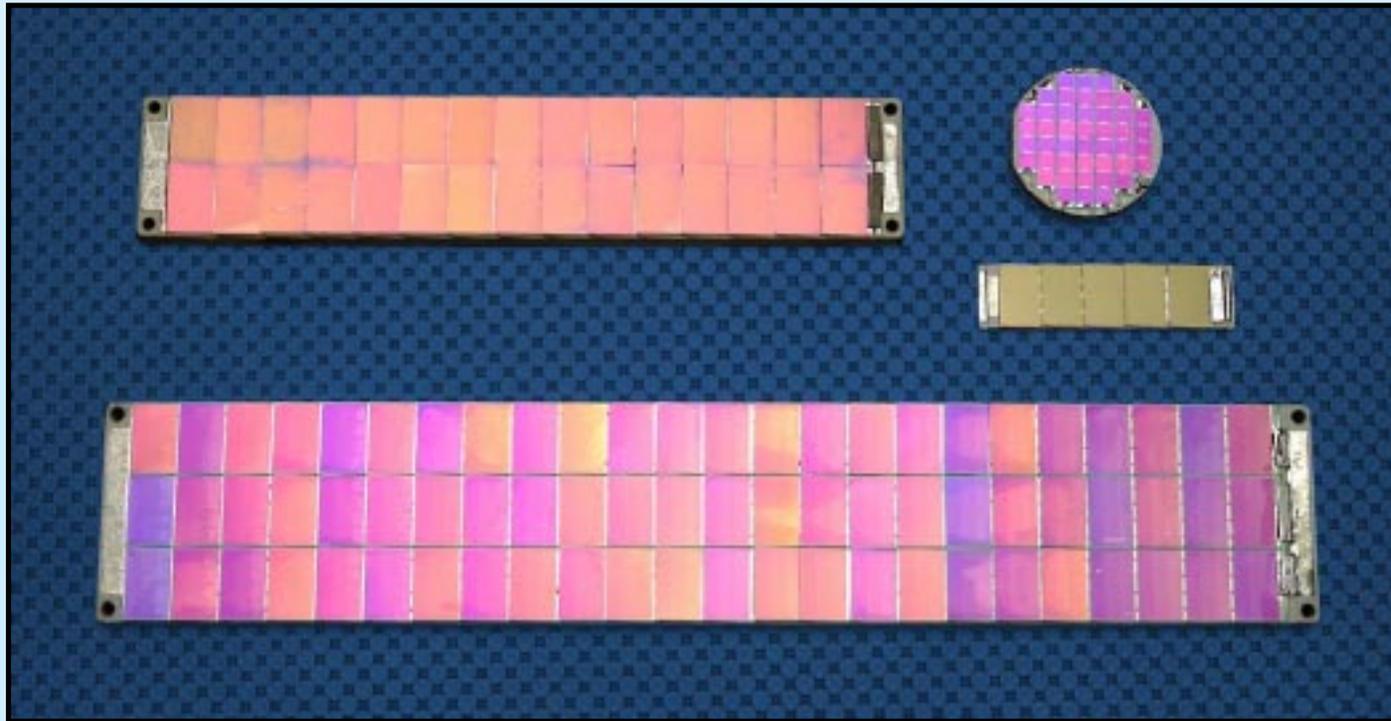
1. Higher quality epi-ready wafers
2. Lower cost epi-ready wafers
3. Higher performance epitaxial devices
4. Higher epitaxial device yields
5. Lower cost epitaxial devices

GaAs/GaSb SOLAR CIRCUITS



Under NASA and BMDO funding, JX Crystals has been developing mechanically stacked circuits of visible light-sensitive GaAs cells on top of its infrared-sensitive GaSb cells. Mounted in solar concentrators, these circuits achieve solar power efficiencies greater than 30%.

GaSb THERMOPHOTOVOLTAIC CELL CIRCUITS



Under Army, DARPA, DOE and internal funding, the company has made circuits of its infrared-sensitive photovoltaic cells for use in fuel-burning electric generators, and cogenerators of heat and power, including the thermophotovoltaic systems shown on the remaining slides. The largest circuit shown here uses 72 of the company's standard 2 cm² GaSb cells. This 2" * 11" circuit is the basic building block of several of JX Crystals' TPV systems.

THERMOPHOTOVOLTAIC (TPV) SYSTEMS

- 100 Watt off-grid cogeneration



World's first TPV heat and power system:

- ◆ burns propane or natural gas
- ◆ delivers 25,000 BTU/hr of heat
- ◆ cogenerates 100 Watts of DC electricity
- ◆ uses two of the 2" * 11" circuits
- ◆ 20 beta site Midnight Sun® Stoves sold

THERMOPHOTOVOLTAIC (TPV) SYSTEMS

- One Kilowatt on-grid cogeneration

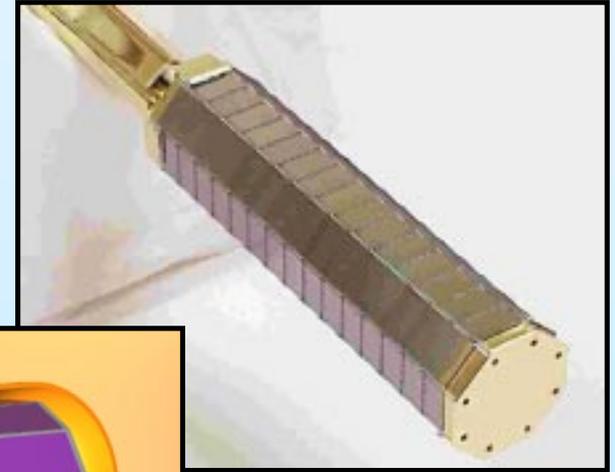
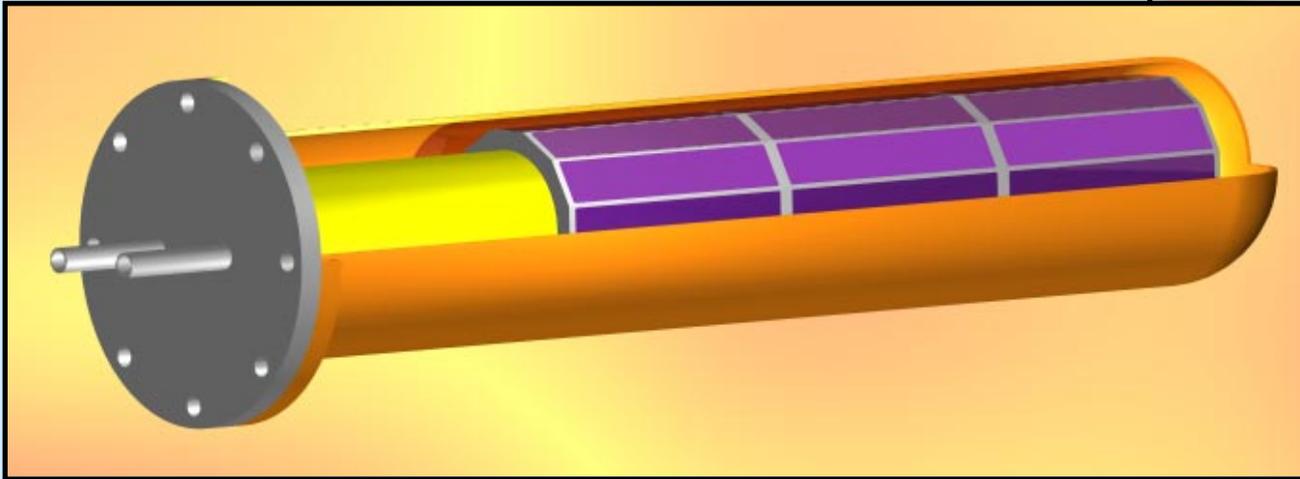


Prototype 500 Watt to one kW
TPV system:

- ◆ burns any fuel
- ◆ will replace home furnace with combined heat and power, using 90% of the fuel's energy
- ◆ developed for military battery charging
- ◆ uses eight of the 2" * 11" circuits

TPV SYSTEMS

- Industrial generation using waste heat



Industrial TPV systems: by putting circuits inside a ceramic tube in the waste stream of a glass or steel furnace, electricity can be generated for “free”. A small prototype has been built, (shown here without the surrounding tube) which operates in an electric oven. Full scale systems will:

- ◆ measure 6 feet by 8 inches
- ◆ generate 5 kilowatts
- ◆ operate virtually all year
- ◆ be clustered by the hundreds in a facility to generate up to 1 MW